Skin Marker

Skin Marker Results:

The overarching concept of this design was to produce a marker which could maximise its visibility across a range of modalities including MRI, CT, CRT, 3D surface scanning (Laser and photogrammetry) and other optical methods (digital photography/ video). By providing a standard marker across all required methods of imaging would increase the volume, reduce the cost and provide a common marker which could be ordered in bulk for a range of hospital departments. From a user point of view a simple, familiar unit which had the same user/ placement errors would bring a level of consistency/ standardisation to the marker placement process. A skin marker was tested under a range of different modalities including initial prototypes (Figs 1-3) and a modified skin marker (Fig. 9). The design included several features which could be either treated as modular or integrated. These included:

1. Multiform tabbed carrier. This design was provided with 2, 3 and 4 tabs providing increased surface area for adhesive to the skin. The joint of each tab had a cut out providing greater flexibility at the junction of the tab and the central body. The multiform carrier was suitable for screen printing which included chroma-key (Green) and black for recognition by different optical modalities. These included photography and 3D surface scanning.
2. A radiopaque gel. This gel included a base material and a range of additives to be visible in both MRI, CT and CRT. Tests were made and although some good results were achieved in some modality settings across MRI CT and CRT, however some MRI scans were unsuccessful. At this time the gel is unresolved as a suitable substance for all setting in all these modalities. Discussed further later in this document.
3. A protective dome to encase the gel has been designed with several iterations which may be of interest. Originally a transparent dome was envisaged with a close to transparent gel/liquid (e.g. Vitamin-E oils). This provided a lens effect and assisted precision positioning. A test on 420 marker placements resulted in precision location of 0.5mm (±0.35). The gel substances tended to be opaque therefore another iteration of the dome was suggested with a moulded polymer conical lens section, with the Gel filling a doughnut type cavity in the remaining space of the dome. Another iteration includes a black only dome cover. This has been proposed for two reasons. Firstly if the lens is not desirable then no transparency is required and secondly increased black area produced a more clearly defined hole in the mesh of 3D photogrammetry modalities. The dome's geometric shape provides a clearly visible contrast form from the non uniform geometry of human anatomy. This form is also easily identified by computer algorithms due to its recognisable form from any angle.

Some early features such as metallic inks were intended for visibility in CT and CRT. These were very faint and deemed ineffective.

Section 1: Marker tests Phase 1

Lens feature and positioning

During the initial test of the marker for palpation and positioning under Upright MRI imaging, it was discovered that the liquid within the capsule provided a lens feature. This was further developed in more recent design proposals. Pen ink marked on the skin was tattooed onto the back of the adhesive marker on removal providing a clear positioning reference (Fig. 4).The lens feature was tested for repeatability using CAD measurement (Fig. 5) and for positioning accuracy (Fig. 6). The chromo-key colour also provided clear visibility using digital photography (Canon IXUS 7MP camera) and a computer algorithm (fig. 8).

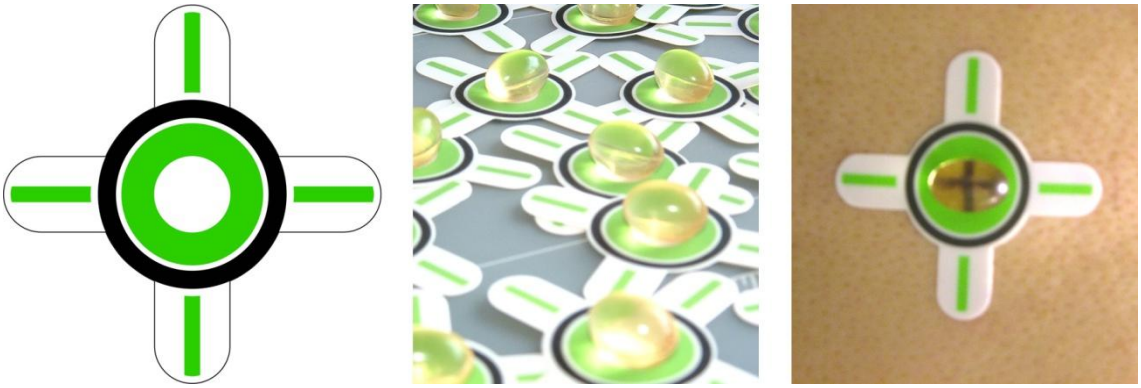


Fig 1. Original prototype cruciform marker with Vitamin-E capsule

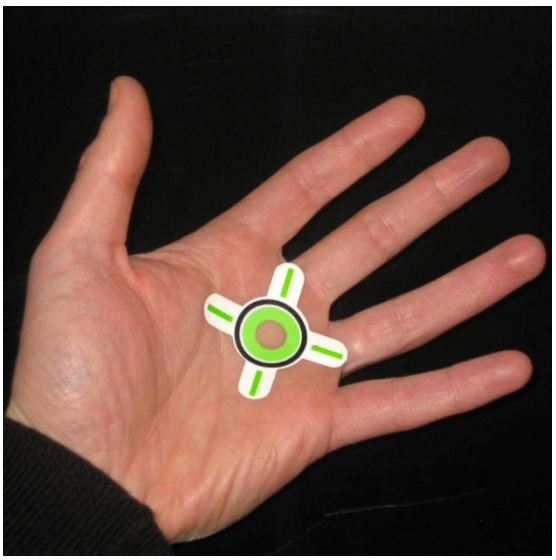


Fig. 2. Marker transparent window

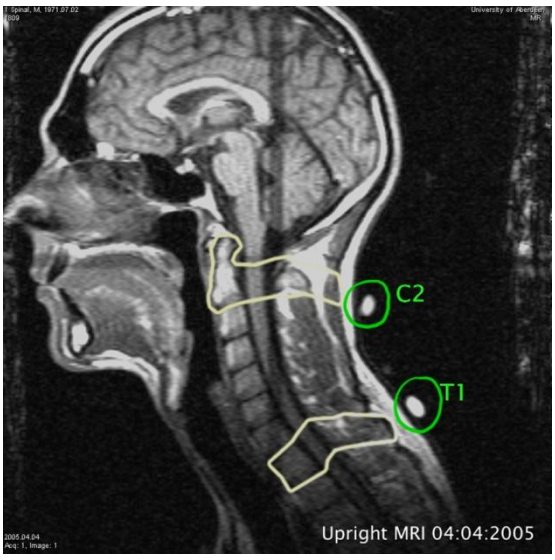


Fig. 3. Fonar Upright MRI scan with markers

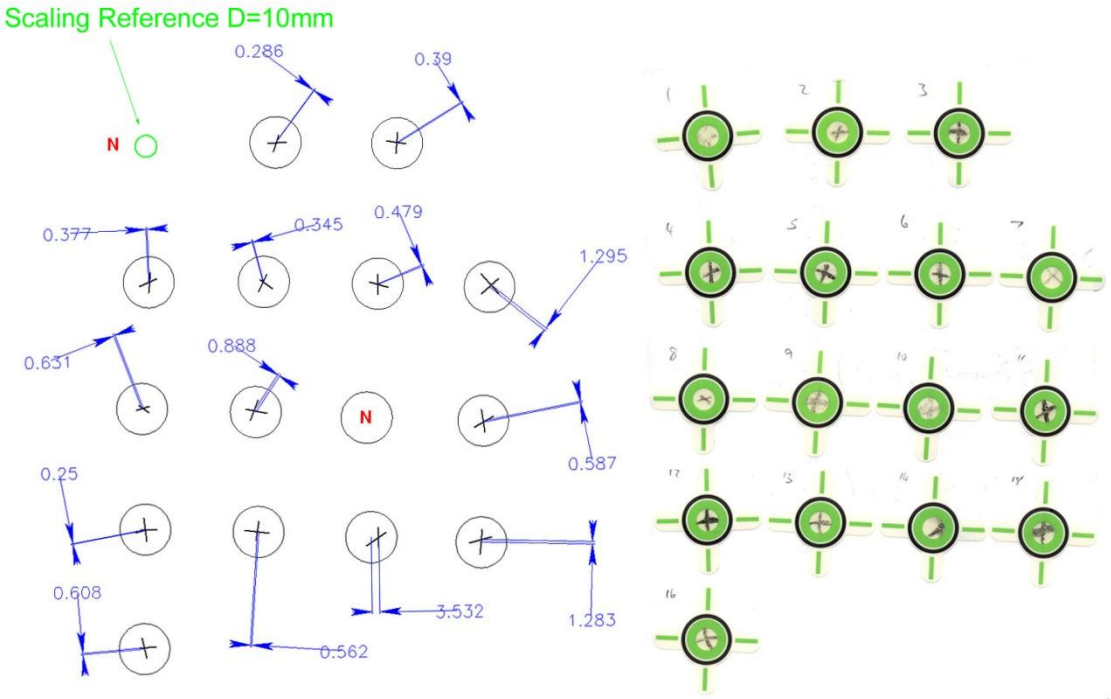


Fig. 4 Calibration study body marker position test, *n*=28 pilot study, (participant F01)

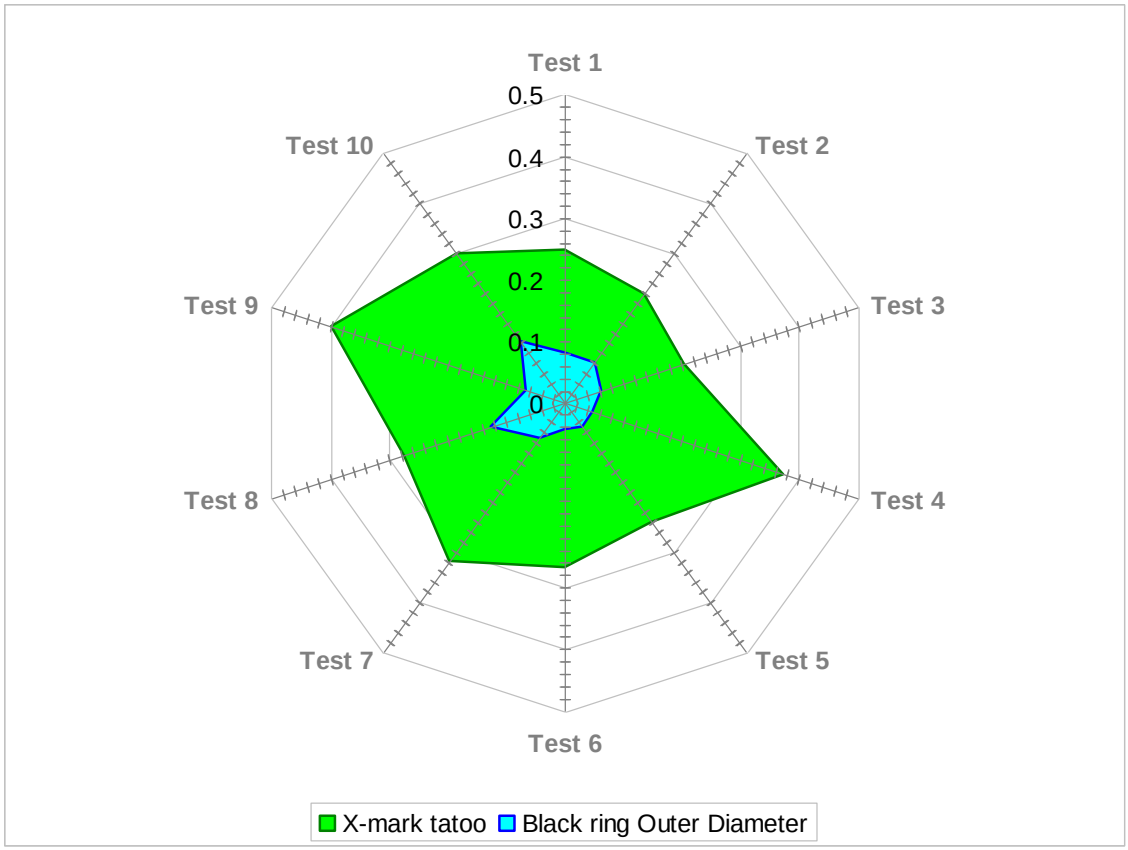


Fig. 5 CAD measurement repeatability test (*n*=10)

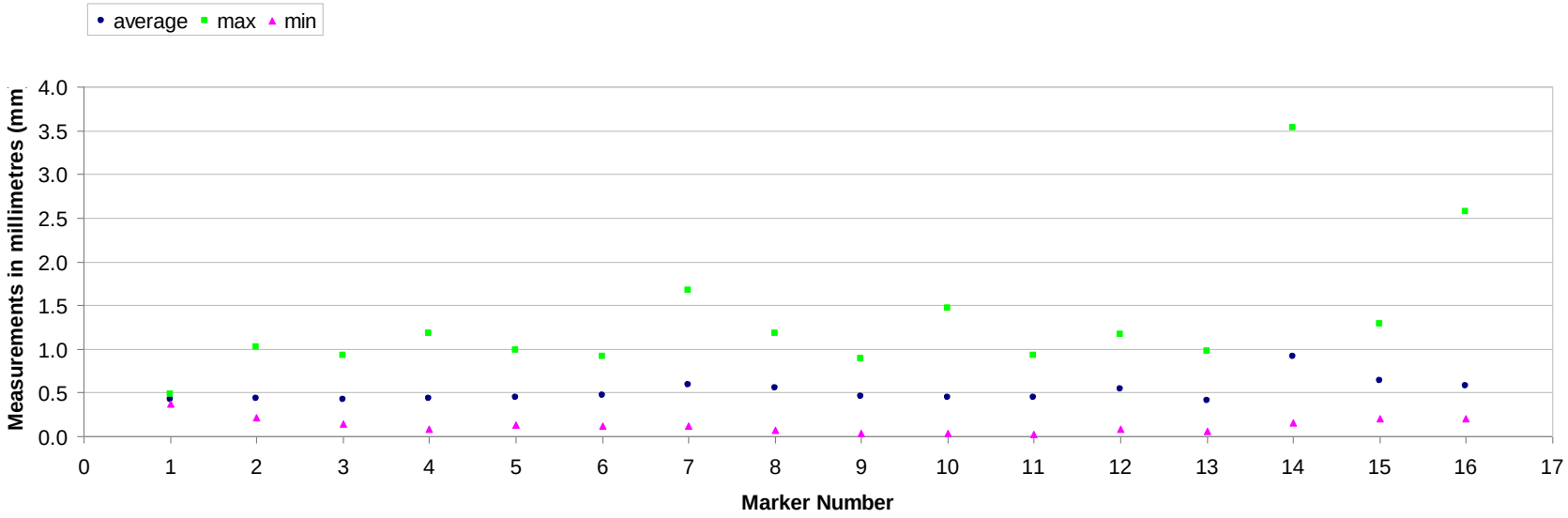


Fig. 6 Body marker placement measurements for n=30 subjects (*n*=420 markers out of 480)

The body marker adhesion performed very well with 99.4% of the markers remaining in place. However the firm adhesion introduced some additional issues for consideration. It caused significant restriction when attached, affecting the ease of flexion / extension exercises prior to the digital photograph procedure, in the neck region. One participant's skin reddened after removal of the body markers (Fig. 7) and all others appeared to be unaffected. The modified marker therefore included the Duo and tri form designs and integrated the semi-circular cut out in the region of the tab to main body junction.

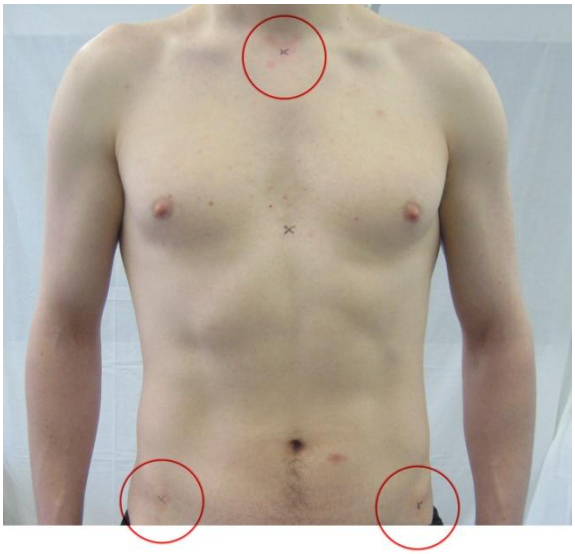


Fig. 7 Skin irritation from marker on (participant M05)

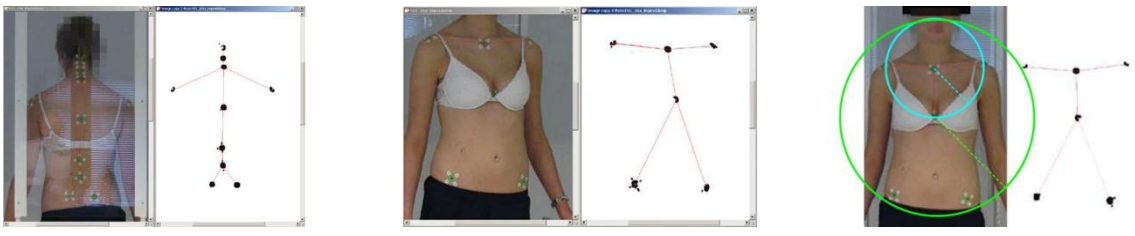


Fig. 8 Feature tracking and scene registration for front and back images

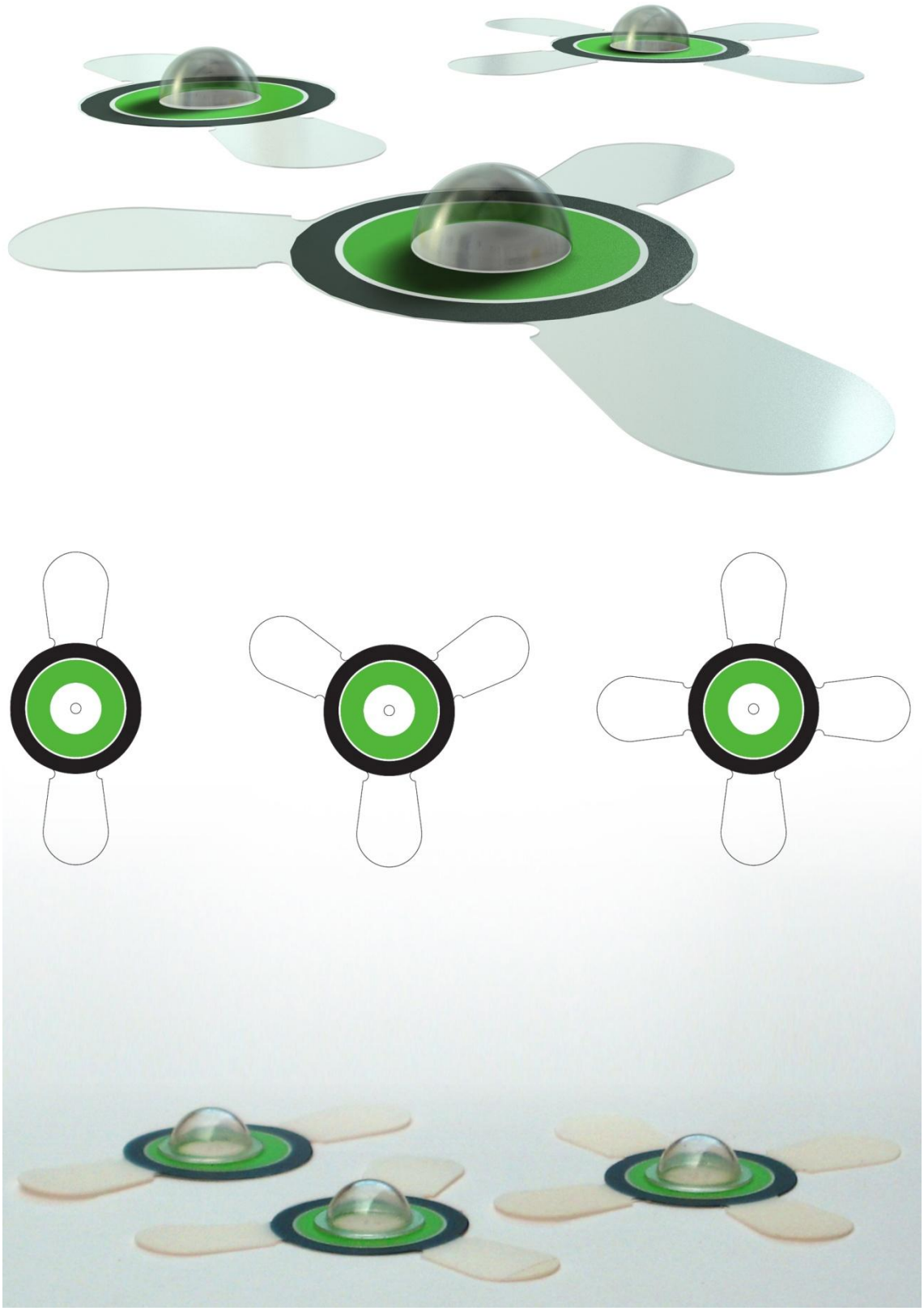


Fig. 9 Modified Skin marker 2009 (CAD and prototypes)

Section 2: Marker Tests Phase 2

3D surface scanning

Various marker components were on different imaging modalities. These were conducted in 2009 and showed potential for our marker.

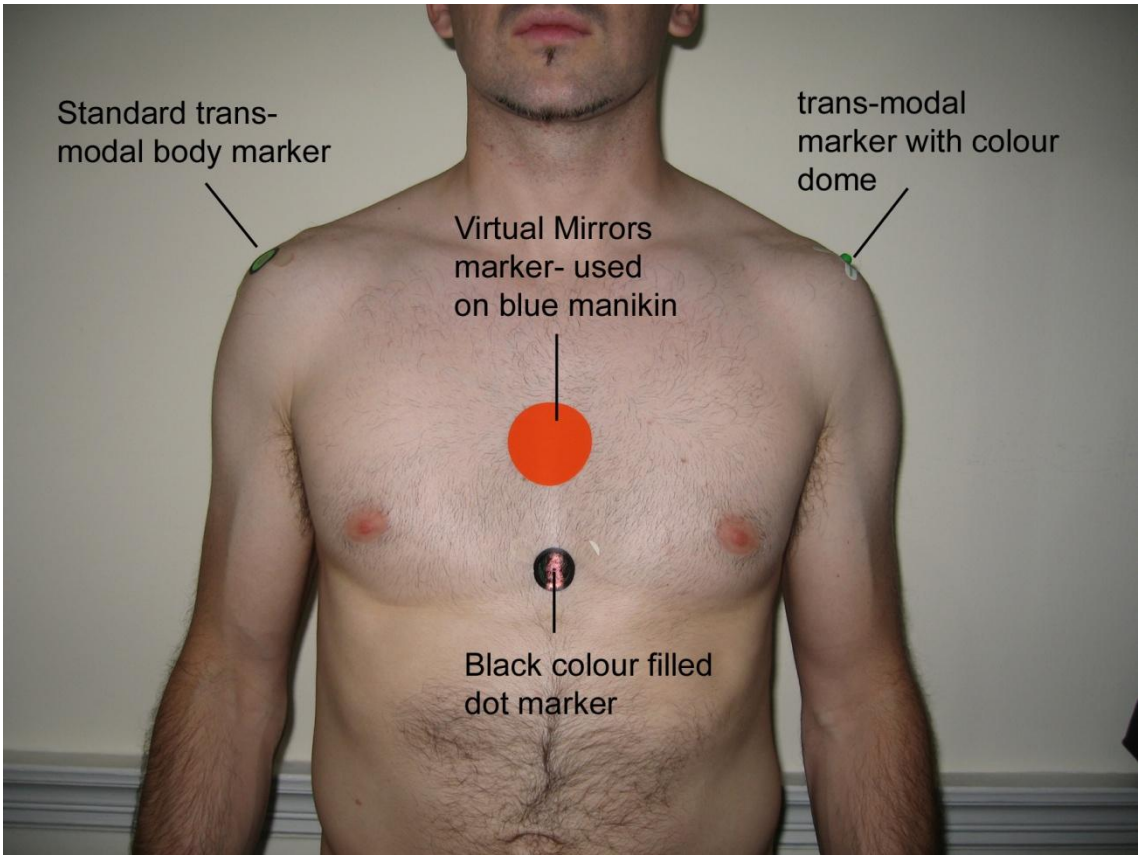
1. Wicks and Wilson 3D body scanner (white light surface scanning)- test of black ink recognition
2. TC2 Body scanner (white light surface scanning) - test of black ink recognition
3. 0.2Tesla MRI- Test of Hydrogel (pure) substance
4. Bespoke Computer algorithm for colour extrapolation of Green reflective ink values.
5. An x-ray study using an Adani System- test of a marker with a barium sulphate additive.

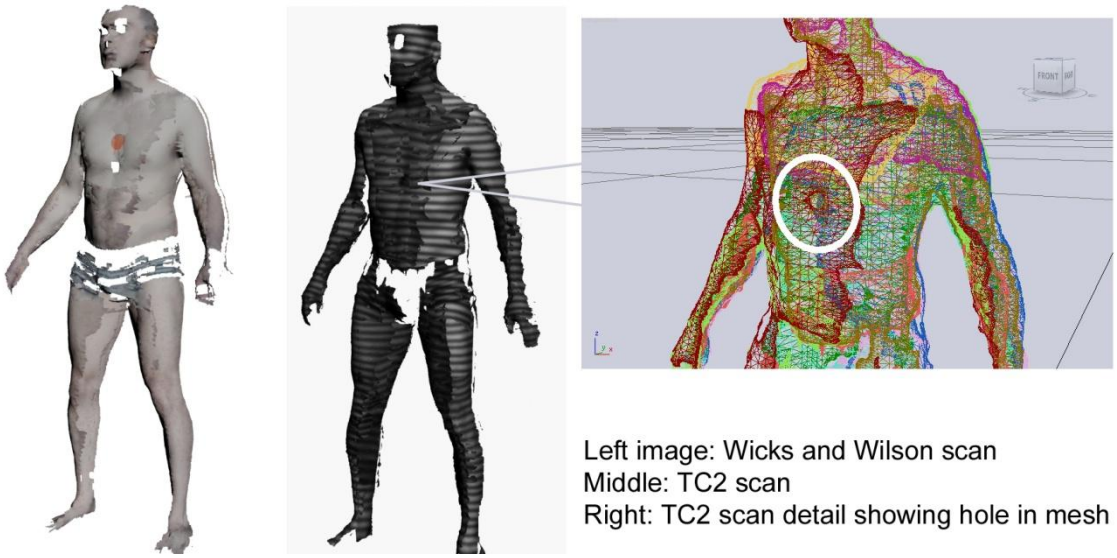
The results of these tests were largely positive.

1. The black ink ring was too fine but a larger black dot of diameter 20mm + was clearly visible making a hole in the surface mesh in both the Wicks and Wilson and TC2, 3D Scanning systems (Fig. 10)

Note: The 3D scanning process does however have limitations due to the view angles of the cameras. An invisible zone exists at certain areas of anatomy using this method which the software compensates when building a surface mesh. Therefore marker position or patient orientation is important when using markers.

2. The gel was significantly more luminous for T1 and T2 weighted scans compared against a vitamin E (cod liver oil) capsule and comparable to the MRI liquid phantom. We did not quantify this value, but rather observed its notable luminance (Fig 11)
3. The initial additives although visible did not provide a strong enough signal and the amounts required significant increase in percentage terms (1-5%). The silver ring under print was also very dim (Fig 12)





Left image: Wicks and Wilson scan
Middle: TC2 scan
Right: TC2 scan detail showing hole in mesh

Fig. 10 Results of the 3D Scanning tests.

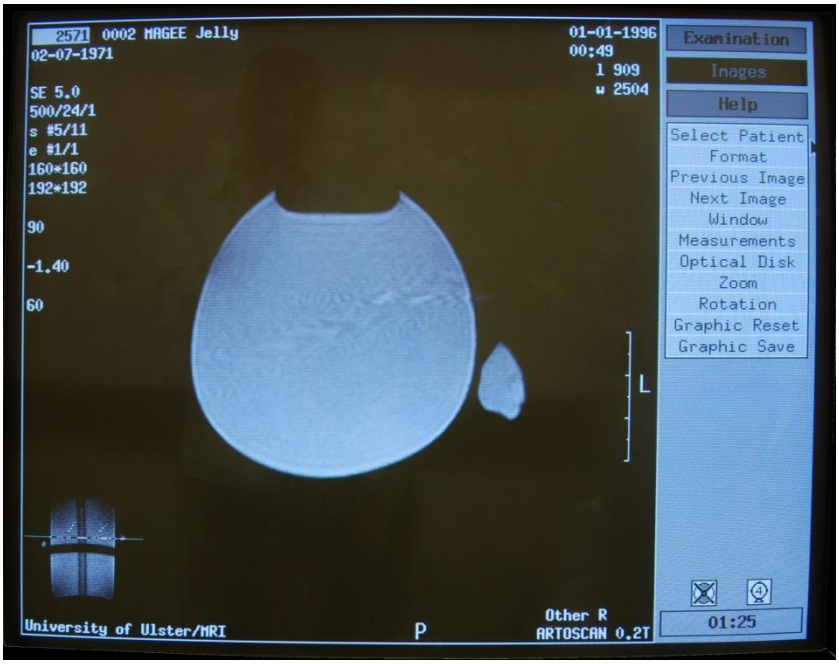


Fig. 11 HydroGel (pure) compared to the Phantom material (0.2T)

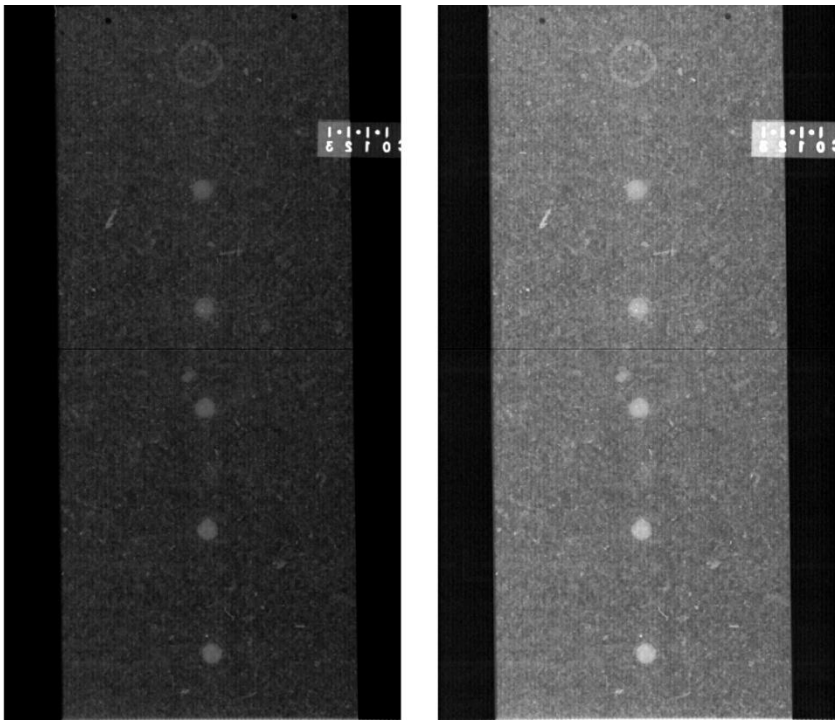


Fig. 12 Adani CRT images of Barium (1-5%) Gels and silver ring print (standard and enhanced images)

Section 3: Marker Tests Phase 3

We tested a modified marker which contained a Hydrogel with Barium Sulphate additive in significantly higher amounts (5-35%). This substance was known to have barrier qualities in MRI but it was hoped that the extremely strong signal of the hydrogel would counteract this reaction. We also had to use standardised imaging equipment (1.5T Siemens MRI and Digital X-Ray systems) and anatomically realistic phantoms to ensure that the clinical conditions were more representative (Figs. 13-16).

Radiography: We also tested using the markers with CRT (Fig. 17) and CT (Fig. 18). Some quantitative assessment has been made using Analyse and Osiris software to extract a CT number, from the CT scan. The optimum percentage of Barium Sulphate at the point of peek visibility before levelling off of signal was identified as 25% per volume of marker.

MRI: We used a Siemens 1.5Tesla system with a cylindrical phantom. A series of scans were conducted including T1 (Figs. 19 and 20), variants of T2 (Fig. 21), spin echoes, gradient echoes and gradient density weighted scans. Some of these were clearly visible, however in some the Barium sulphate created to strong of a barrier and the signal was lost (Gradient density and one of the T2 variants).

A silver print feature although visible was just visible. This feature was a test for an under print (beneath the black ink) to test if this simple technology had merit for radiography. It was further confirmed as an ineffective feature.

Present Status

We are now exploring the use of Gadolinium to boost MRI signals with the optimised percentage of Barium Sulphate identified earlier. The idea being that the gadolinium will boost the MRI signal and counteract the successful BaSO4 additive in CT, CRT and some of the MRI scans. CT numbers (unit used in Osiris) will also be conducted on these studies once the correct. So far an initial test in the 0.2T MRI showed that additive of 1-5% Gadolinium (3 variants) produced signals with reduced signals as the amount of additive was increased. It is unclear at this stage how much gadolinium will add a peak to the signal. We envisage this to be a longer process than first anticipated and utilization of existing multimodal gels may be appropriate in conjunction with our other design features of this unique skin marker. Its general design specification is included in table 1.

Fig. 13 CRT image process of head and shoulders anatomy phantom and markers

Fig. 14 CT scan of head and shoulders phantom and markers

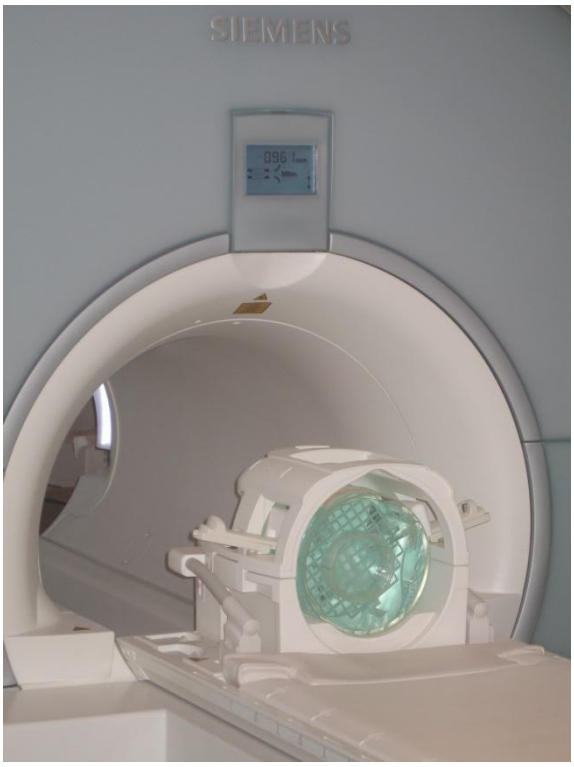


Fig. 15 MRI scan of phantom and markers

Fig. 16 MRI phantom hosting a cluster of markers and marker substances with various percentages of Barium Sulphate including vitamin E capsule.

Fig. 17 CRT image with all body markers providing high visibility

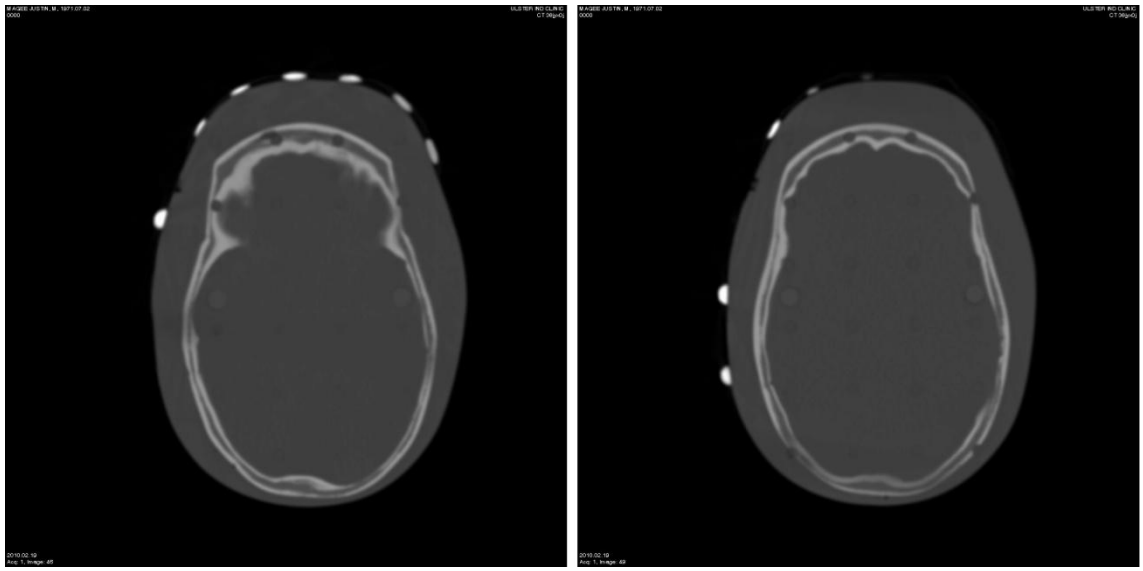


Fig. 18 CT scans illustrating body markers with increased visibility with increased BaSO4

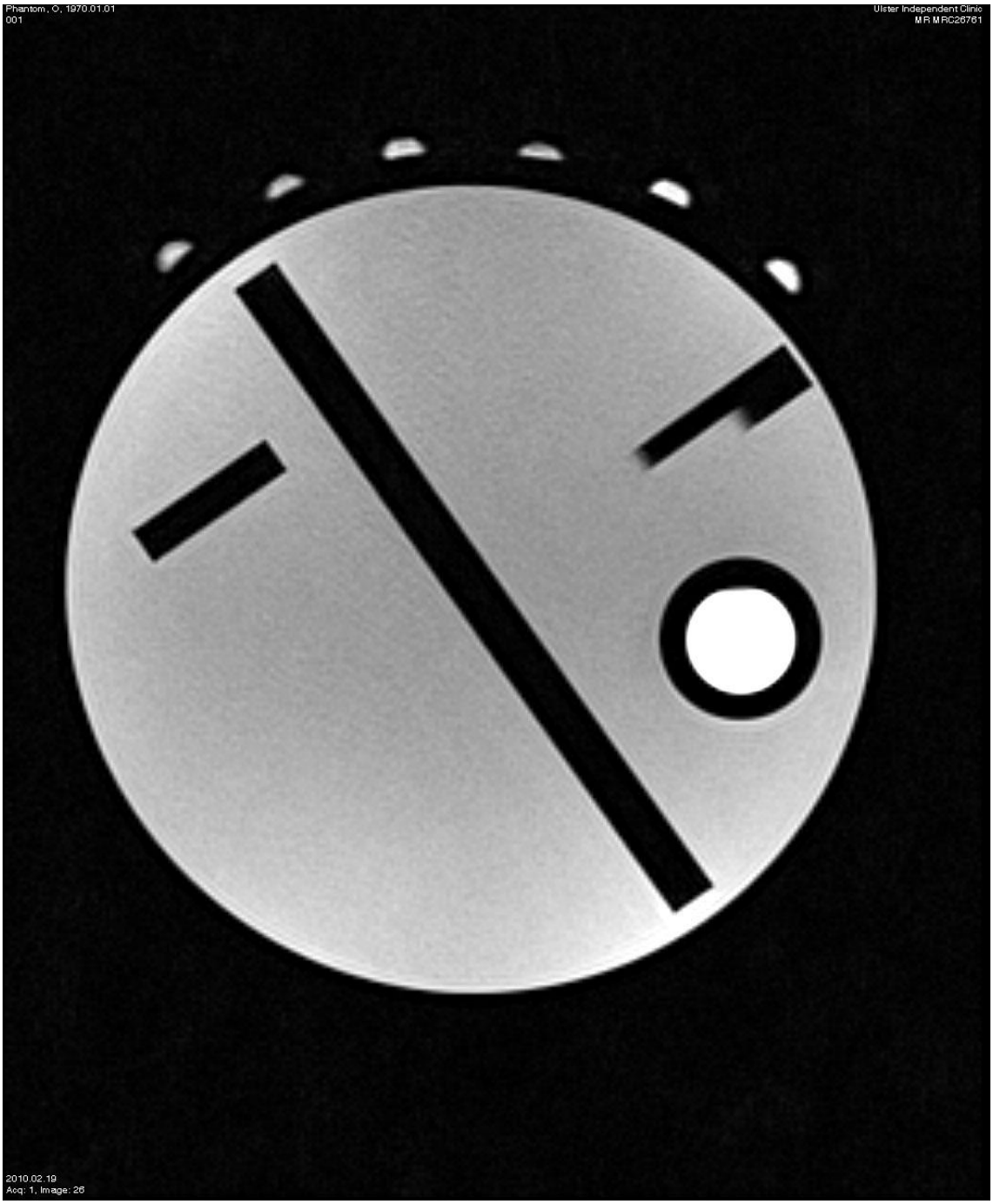


Fig. 19 Short T1 (STIR) coronal scan showing increasing visibility with reduced BaSO4

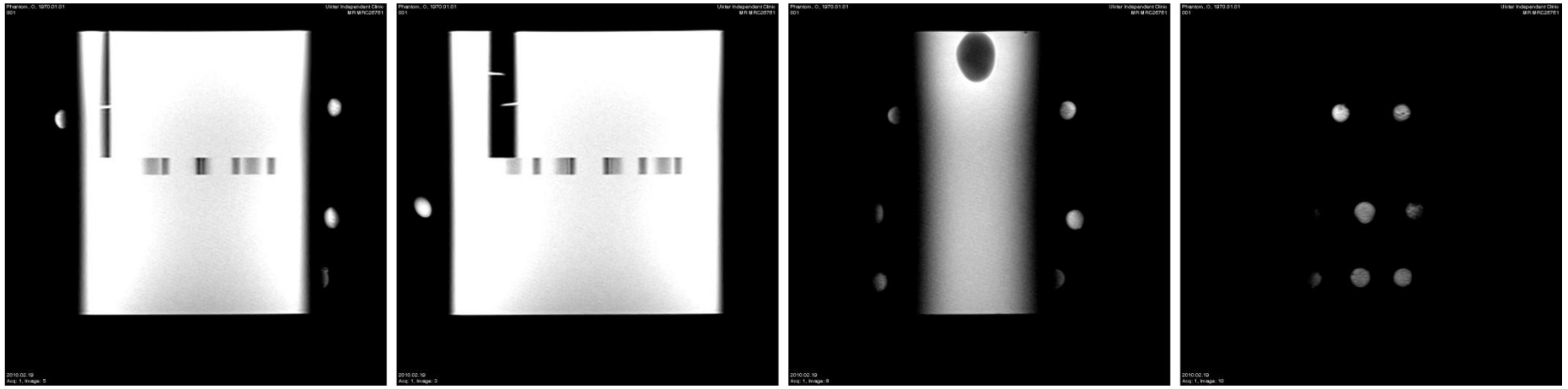


Fig. 20 T1 coronal Scans illustrating visibility of markers and Vitamin-E capsule

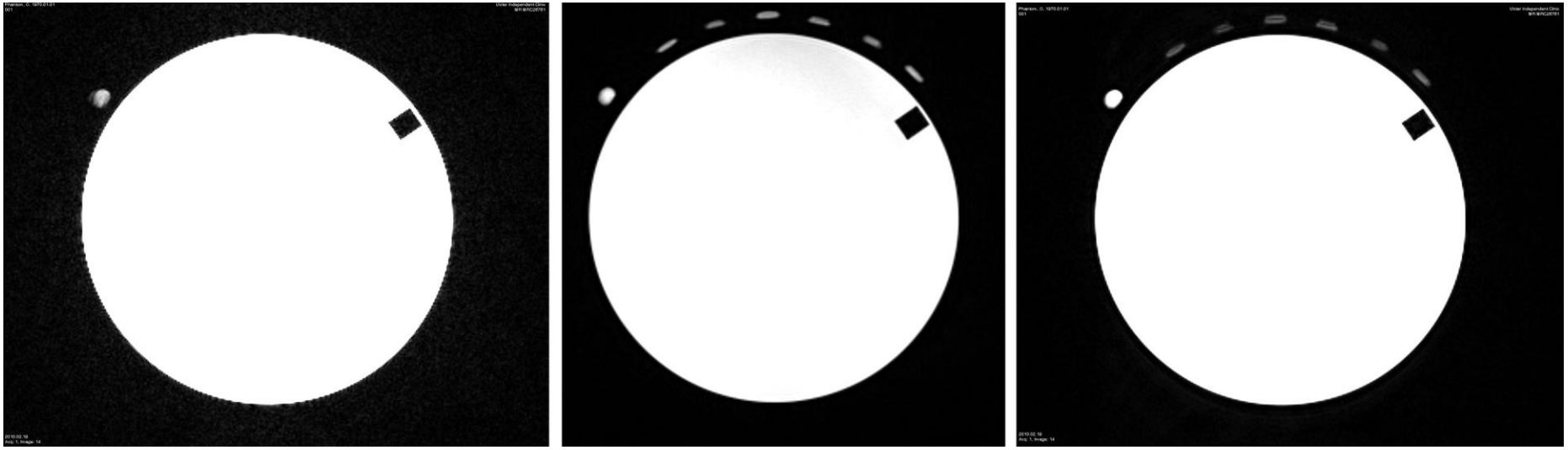


Fig. 21 T2 Transverse Scans illustrating the visibility of the Vitamin-E capsule and body marker gels (squashed) at different settings

Table 1: Skin Marker Features				
Feature	**Material**	**Colour / description**	**Dimensions**	**Modality**
Cruciform/ tri-form and duo-form labels	PC or PET film-carrier for graphics	Transparent- matt finish	W=50 L=50 T=0.125mm	N/A
Dome	In-mould or retro-fit attached to labels	Transparent- matt finish Or	D=10mm Range=5-25mm	• 3D scanning (Laser, photogrammetry, Moiré Fringe) • Ultrasound • Computer algorithms (optical)
		Black Or		• Increased visibility for photogrammetry
Dome insert	Hydro gel	Transparent (maximum volume) based on 10mm diameter dome	V=261.2mm3 (10mm hemispherical dome)	• MRI
Dome insert additives	Gadolinium salts Barium Sulphate	Cloudy opaque Cloudy opaque	TBD 25% volume (optimum)	• MRI , CT, CRT
Adhesive backing	Duplomed®	Transparent	T= nominal	
3D scanning graphic	Colour over print	Black (CMYK= 75,68,67,90) Circular ring	A=192.2mm2 D=25.0mm d=19.5mm	• Moiré Fringe
Reflective graphics	Colour over print	Green (CMYK= 62,0,100,0) Circular ring	A=190.3mm2 D=18.5mm d=10.0mm	• Camera/ Video capture